Useful Tips for Successful RF Ablation Originated from Papillary Muscle, Purkinje System, and Cardiac Crux

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What is the Cardiac Crux VT?
Cardiac Crux area

The cardiac crux is the posterior-septal space characterised as a four sided pyramidal space; the right and the left atrium and the right and left ventricular, respectively\(^1\).

This space contains the right coronary artery, the middle cardiac vein and the epicardial fat. The ECG characteristics and clinical characteristics of idiopathic crux ventricular arrhythmia (VA) has been described in a few prior reports.\(^2\)

The ECG morphology with RBBB and superior axis is common in patients with VAs originating from LV-posterior fascicle (LPF), LV-posterior papillary muscles (PPM) and apical crux area. Therefore, it is challenging to distinguish these VAs due to similar ECG morphology and vicinity of area.

Study population
Among 1021 patients with idiopathic VA referred for ablation, 18 patients (mean age; 53 years old) were identified with crux-VA. All patients had a symptomatic idiopathic VA and 3 patients had an ICD implantation because of hemodynamic collapse associated with rapid VT. All patients had a normal ejection fraction with no evidence of significant coronary artery disease.
Mapping and ablation algorithm for crux-VA.

Baseline clinical characteristics of patients (Crux VA vs other form of idiopathic VA)

<table>
<thead>
<tr>
<th></th>
<th>Crux VA (n=18)</th>
<th>Idiopathic VA (n=251)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>53 ± 12</td>
<td>48 ± 21</td>
<td>0.07</td>
</tr>
<tr>
<td>Male</td>
<td>8 (44 %)</td>
<td>115 (46 %)</td>
<td>0.81</td>
</tr>
<tr>
<td>Symptoms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asymptomatic/Palpitation</td>
<td>10 (56 %)</td>
<td>201 (80 %)</td>
<td>0.01</td>
</tr>
<tr>
<td>Syncope/Cardiac arrest</td>
<td>8 (44 %)</td>
<td>50 (20 %)</td>
<td>0.01</td>
</tr>
<tr>
<td>Arrhythmias</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VT/NSVT</td>
<td>15 (83 %)</td>
<td>83 (33 %)</td>
<td>0.001</td>
</tr>
<tr>
<td>PVC</td>
<td>3 (17 %)</td>
<td>168 (67 %)</td>
<td>0.001</td>
</tr>
<tr>
<td>QRS duration (msec)</td>
<td>150 ± 27</td>
<td>138 ± 19</td>
<td>0.04</td>
</tr>
<tr>
<td>LV ejection fraction (%)</td>
<td>60 ± 5</td>
<td>58 ± 8</td>
<td>0.26</td>
</tr>
<tr>
<td>ICD implantation</td>
<td>3 (17 %)</td>
<td>7 ( 3 %)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Case 1
Fascicular VT

35 years old, male.
He had palpitation and had VT.
He had no structural heart disease.
ECG

Ventricular tachycardia

Sinus rhythm

HR 248 /bpm, CRBBB+superior axis, QRS 120 msec
VT termination

P1: diastolic potential
P2: presystolic purkinje potential

(100mm/sec)
Catheter Position

EPS

Sinus Rhythm

P1: diastolic potential
P2: presystolic purkinje potential

(100mm/sec)
Schema of the ablation point and Intracardiac ECG

Ablation point

① point ablation at the earliest ventricular activation with a fused P2.
② liner ablation to transect the involved middle to distal left fascicular tract

P1 Block

P1-P2 interval was gradually prolonged during ablation. After P1 block, VT wasn’t induced.
Mapping and ablation of Fascicular VT

Mapping

LV septal mapping using a multipolar electrode catheter is useful. Activation mapping is not typically required, however the ability to tag catheter positions of interest is often helpful. The diastolic potential (P1) and Purkinje potential (P2) can be recorded during VT from the mid-septum. Because P1 has been proved a critical potential in the VT circuit, this potential can be targeted to cure the tachycardia.

Ablation

P1 is the antegrade limb of the VT circuit. The earliest P1 is not need. The distal third of P1 potential is usually targeted to avoid LBBB or AV block. If FVT isn’t induced, we perform an anatomic liner ablation to transect the involved middle to distal left fascicular tract.
Case 2
Papillary PVC

56 years old, male.
He had palpitation and had PVC.
He had no structural heart disease.
Surface ECG during appearance of PVC

PVC: CRBBB+superior axis, QRS 162 msec
How to extract a papillary muscles?
First, we position a sound-star at a His area. We advance a sound-star toward apex in a posterior deflection. We can easily see LV long axis view and papillary muscle in a clockwise.
Successful ablation site

(A) Intracardiac ECG

(B) Fluoroscopic view

V-QRS = -48 msec
Mapping and ablation method of Papillary VT/PVC

• **Mapping**
  Intracardiac echocardiography (ICE) is essential to ensure adequate catheter-tissue contact and correct orientation of the catheter tip. We use a Carto system and the CartoSound module allows integration of the anatomic shell based on the echo images with real-time integration of the ICE views.

• **Ablation**
  Ablation is challenging as compared to those with other VAs probably because of the deep location of the origin and the difficulty in maintaining stable contact of the catheter tip at the papillary muscles. Targets for ablation include sites with earliest ventricular activation and a QS in the local unipolar recording. These sites usually exhibit an excellent pace map.
How to differentiate VT Originating from

- Posterior Papillary Muscles
- Posterior Fascicular
- Apical Crux. ? ?
We studied 40 patients who underwent successful catheter ablation of idiopathic VA from
Posterior papillary muscle (PPM, n=15),
LV posterior fascicle (LPF, n=18),
Apical cardiac crux (crux, n=7).
Baseline characteristics

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Patients characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All patients</td>
</tr>
<tr>
<td>No. of patients</td>
<td>40</td>
</tr>
<tr>
<td>Age (years)</td>
<td>49 ± 10</td>
</tr>
<tr>
<td>Gender, male</td>
<td>21 (52%)</td>
</tr>
<tr>
<td>Ejection fraction (%)</td>
<td>58 ± 8</td>
</tr>
<tr>
<td>History of ventricular tachycardia</td>
<td>22 (55%)</td>
</tr>
<tr>
<td>History of syncope/cardiac arrest</td>
<td>6 (15%)</td>
</tr>
<tr>
<td>Successful ablation</td>
<td>29 (73%)</td>
</tr>
<tr>
<td>Endocardium</td>
<td>2 (5%)</td>
</tr>
<tr>
<td>Epicardium</td>
<td>N/A</td>
</tr>
<tr>
<td>Medical therapy [n (%)]</td>
<td></td>
</tr>
<tr>
<td>Amiodarone/sotalol</td>
<td>5 (13%)</td>
</tr>
<tr>
<td>Flecaïnide</td>
<td>2 (5%)</td>
</tr>
<tr>
<td>Beta-blocker</td>
<td>12 (30%)</td>
</tr>
<tr>
<td>Calcium blocker</td>
<td>14 (35%)</td>
</tr>
<tr>
<td>Electrocardiography</td>
<td></td>
</tr>
<tr>
<td>QRS duration (ms)</td>
<td>141 ± 18</td>
</tr>
<tr>
<td>MDI &gt; 0.55</td>
<td>7 (17%)</td>
</tr>
<tr>
<td>QS in II</td>
<td>18 (45%)</td>
</tr>
<tr>
<td>Monophasic R in aVR</td>
<td>9 (23%)</td>
</tr>
<tr>
<td>qR in V1</td>
<td>13 (32%)</td>
</tr>
<tr>
<td>QS or r/S &lt; 0.15 in V6</td>
<td>9 (23%)</td>
</tr>
</tbody>
</table>

LPF = left ventricular posterior fascicle; LV PPM = left ventricular posterior papillary muscle; MDI = precordial maximal deflection index; N/A = not applicable.

*P < .05

Panel A shows that the R/S ratio in V6 was significantly lower in patients with apical crux VA compared to those with other VAs.

The R/S ratio also tended to be lower in patients with PPM VA compared to those with LPF VA ($P = .06$).

MDI was significantly higher in patients with apical crux VA compared to those with other VAs (B).

Furthermore, QRS duration in patients with LPF VA was significantly narrower compared to other VAs.

VA with RBBB and superior axis (n=40)

$MDI \geq 0.55$

YES (7)

Crux (5), PPM (2)

YES (5)

Crux (5)

NO (2)

PPM (2)

NO (33)

Crux (2), LPF (18) , PPM (13)

1) QS or r/S ratio<0.15 in V6 and
2) Monophasic R in a VR

YES (2)

NO (31)

Crux (2)

LPF (18), PPM (13)

1) QRS duration > 150 msec
2) qR in V1

YES (11)

PPM (11)

NO (20)

LPF (18), PPM (2)

This study investigated 13 patients in whom fascicular VT (FVT) was successfully eliminated by ablation at the posterior PM (PPM-FVT, n=8) and anterior PM (APM-FVT, n=5). All patients had no evidence of structural heart disease. The exact location of mapping/ablation catheter was confirmed by real-time intracardiac ultrasound image.
Local ventricular electrograms and intracardiac echo images at the successful ablation site

- Left panel showed the local electrogram at the successful ablation site during procedure. Both diastolic and presystolic Purkinje potentials (P1 and P2) were sequentially recorded during VT.
- Right panel showed the successful ablation site which located on the posterior papillary muscles by real-time intracardiac ultrasound image.
This study investigates another distinct subtype of verapamil-sensitive FVT originating from the Purkinje network around the papillary muscles.
Comparison of Fascicular VA and Papillary muscle VA

Fascicular VA

- Narrow QRS < 150msec
- VT > PVC
- Young age
- P1 and P2 preceding ventricular activation
- Verapamil-sensitive termination or slowing of tachycardia
- Induction and entrainment with ventricular and atrial pacing

Papillary muscle VA

- Wide QRS > 150msec
- VT < PVC
- Verapamil is no-sensitive
- Anatomic landmarks and successful ablation site located in mid-inferior LV region by ICE

PPM - Fascicular VT

Diastolic Purkinje potential is recorded at the papillary muscle during VT. Ablation of the diastolic potentials is highly effective for suppressing this arrhythmia. Although PM-FVT is sensitive to verapamil administration, it is not as highly sensitive as the common type of left FVT.
1) Clinical and electrophysiological characteristics are important for fascicular VA. Patients with FVT are younger as compared to those with other VAs. FVT is narrower with QRS duration as compared to those with other VAs. Purkinje potentials (P2) and diastolic potentials (P1) are preceding ventricular activation during VT.

2) Anatomic landmark by intracardiac echocardiography is important for papillary muscle-VAs. QRS duration with PPM-VAs are wider as compared to those with fascicular VT. In PPM-VA, PVC is more frequently than VT.

3) It is challenging to distinguish from PPM-VA and LPF-VA due to overlap of successful ablation point. Therefore, we need to judge these VAs comprehensively.
Thank you for your attention